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REPORT ON THE SECOND UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOP ON BASIC SPACE SCIENCE FOR DEVELOPING COUNTRIES, CO-SPONSORED BY THE EUROPEAN SPACE AGENCY AND THE PLANETARY SOCIETY, ORGANIZED IN COOPERATION WITH THE GOVERNMENTS OF COSTA RICA AND COLOMBIA AND HOSTED BY THE UNIVERSITY OF COSTA RICA, THE INTERNATIONAL CENTRE FOR PHYSICS AND THE UNIVERSITY OF THE ANDES

(San José, Costa Rica, and Santa Fe de Bogotá, Colombia, 2-13 November 1992)

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INTRODUCTION

A. Background and objectives

1. The General Assembly, at its thirty-seventh session, adopted resolution 37/90 of 10 December 1982, endorsing the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) that the United Nations Programme on Space Applications should promote the growth of indigenous nuclei and an autonomous technological base in space technology at the local level. At its thirty-fourth session, in June 1991, the Committee on the Peaceful Uses of Outer Space endorsed the United Nations Programme on Space Applications for 1992 as recommended by the Scientific and Technical Subcommittee of the Committee at its twenty-eighth session. Subsequently, the General Assembly, at its forty-sixth session, endorsed the activities of the Programme on Space Applications for 1992 (resolution 46/45).

2. The second United Nations/European Space Agency (ESA) Workshop on Basic Space Science for Developing Countries was part of the 1992 activities of the Programme on Space Applications. The Workshop was co-sponsored by the European Space Agency and The Planetary Society, organized in cooperation with the Governments of Costa Rica and Colombia, and hosted by the University of Costa Rica, San José, Costa Rica, from 2 to 7 November 1992, and the Centre for Physics (CIF) and the University of the Andes, Santa Fe de Bogotá, Colombia, from 9 to 13 November 1992.

3. The objective of the Workshop was to strengthen basic space science in developing countries by addressing the ways and mechanisms through which the following goals can be accomplished:

- To improve the awareness of scientists about current and future scientific and technical aspects of basic space science;

- To enhance scientific cooperation among developing countries;

- To explore avenues of education, training and research on space science subjects for the benefit of developing countries;

- To create on international core group of scientists to pursue the objective of the Workshop.

4. The present report, which covers the background, objectives and organization of the Workshop, as well as a summary of presentations (see annex I to the present report), observations and recommendations made at the Workshop, has been prepared for the United Nations Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants in the Workshop will report to appropriate authorities of the Government, universities and research institutes in their respective countries.

B. Organization and programme of the Workshop

5. Invitations to participate in the Workshop were sent by the United Nations to scientific professionals with substantial experience in one or more of the following areas: (a) basic space science and development; (b) Earth science; (c) solar-terrestrial interaction; (d) solar system science; (e) space astronomy and astrophysics; and (f) education for space science. The Workshop was attended by 122 scientists from 19 countries and 3 international organizations: Argentina, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Czechoslovakia, Germany, Guatemala, Honduras, Mexico, Peru, Sweden, Trinidad and Tobago, United Kingdom of Great Britain and Northern Ireland, United States of America, Venezuela, European Space Agency, United States National Aeronautics and Space Administration (NASA) and United Nations (Office for Outer Space Affairs).

6. Funds allocated by the United Nations and the European Space Agency for the organization of the Workshop were used to cover the cost of international air travel and daily subsistence allowance for 19 participants from 14 countries. The Governments of Costa Rica and Colombia provided the Workshop facilities and local transportation for the duration of the Workshop.

7. In San José, welcoming addresses were presented by Mr. C. Quesada, Vice-President for Research of the University of Costa Rica; Mr. O. Morales, Minister for Science and Technology of Costa Rica; and Mr. N. Jasentuliyana, Chief of the Office for Outer Space Affairs, on behalf of the United Nations.

8. In Santa Fe de Bogotá, welcoming addresses were made by Mr. A. Infante, Rector of the University of the Andes; Mr. E. Posada, Executive Director of the International Centre for Physics (CIF); Mr. N. S. de Rubio, Minister for Foreign Affairs of Colombia; and Mr. P. Lala, Deputy Chief of the Office for Outer Space Affairs, on behalf of the United Nations.

9. The scientific programme of the Workshop (see annex II to the present report) was developed by the United Nations Office for Outer Space Affairs, in collaboration with the European Space Agency and The Planetary Society. The Workshop was scheduled to have two days of plenary and working group sessions and 10 days of special sessions with presentations by invited speakers only. The Workshop sessions were held in an informal style, leaving enough time for informal discussions and a few ad hoc contributions from participants. The afternoon of Tuesday, 10 November, the afternoon of Thursday, 12 November and the morning of Friday, 13 November, were exclusively reserved for working group sessions in which participants discussed in depth the national capabilities to develop programmes and to undertake research activities in basic space science and ways to foster international collaboration in the field. The Proceedings of the Workshop will be published in an international journal of cosmic physics and/or an international journal of comparative planetology.

OBSERVATIONS AND RECOMMENDATIONS

A. Basic space science

10. In order to assist scientists in developing countries in finding the necessary support in the pursuit of basic space science, the United Nations should exert its best efforts to create awareness of the importance of basic space science for national development among decision-makers and the general public. In reconsidering the suggestions of the first United Nations/ESA Workshop on Basic Space Science for Developing Countries, held at Bangalore, India, in 1991 (see A/AC.105/489), participants confirmed the following areas of research as parts of basic space science:

(a) Astronomy and astrophysics;

(b) Solar-terrestrial interaction and its influence on terrestrial climate;

(c) Planetary and atmospheric studies;

(d) Origin of life and exobiology.

11. Participants agreed that the following techniques would be applicable for pursuing basic space science research:

(a) Ground-based optical, infrared and radio observations and radio and optical telescopes with associated equipment;

(b) Remote sensing, both from the ground and from space;

(c) *In situ* measurements from rocket, balloon and satellite platforms;

(d) All measurements from ground-inaccessible windows (e.g., X-ray and others) which could be made only through the use of instruments and telescopes in Earth orbit;

(e) Phased radar techniques.

B. Availability and dissemination of scientific information

1. Access to information

12. The United Nations should urge the major space agencies of the world to supply advanced information regarding various projects to scientists in developing countries so that those scientists may involve themselves in follow-up studies.

13. Considering the very high price of scientific journals and increases in exchange rates of hard currencies, the United Nations should strive to

investigate possibilities under which institutes in developing countries might benefit from existing reduced subscription rates for professional and popular journals. Alternative routes to enhance the availability of this critically important information in developing countries should also be investigated, such as the extension of the initiative taken by some journals, which are available to Latin American institutes at the individual scientist subscription rate.

14. In view of the severe difficulties encountered by researchers in acquiring textbooks, conference proceedings and other materials needed to maintain advanced scientific research, the United Nations should ensure the printing, in association with activities already being carried out by the International Astronomical Union (IAU), the International Centre for Theoretical Physics (ICTP), the European Physical Society (EPS) and the American Institute of Physics (AIP), of textbooks in Spanish and Portuguese on basic space science at the elementary, primary, secondary and undergraduate levels, as well as popular texts on basic space science in those languages.

2. Data archives and data centres

15. The participants emphasized the importance of the availability at the national level of existing basic space science data archives for building up first-rate educational and research capabilities for internationally recognized scientific investigations.

16. The United Nations therefore should urge Member States to select, through internal (national) discussion, local or regional clearing-houses for the highly valuable data archives that are still available at no cost from their producing agencies. The owners should be requested to deliver such data products in a manner conducive to easy dissemination and access at the national level, e.g., the International Ultraviolet Explorer (IUE), the Uniform Low Dispersion Archive (ULDA) and the Planetary Data System (PDS). These clearing-houses (or data centres) would foster the development of national basic space science resources and stimulate international collaboration through the existence of centres of common interest. They would also make highly valued data pertaining to individual countries more accessible to other countries, and consequently enhance awareness of the capabilities of each country.

3. Information management system

17. The participants noted that the United Nations had consulted with institutes and researchers concerning the availability of the above information and the collection of detailed information on bilateral and multilateral arrangements allowing the exchange of students and researchers for learning as well as for teaching purposes. A document containing this information was distributed at the meeting.

18. Recognizing that a country's level of involvement in the activities in basic space science is invariably associated with existing economic conditions, the participants recommended the development of new initiatives originating in developing countries for deeper involvement in basic space science. They recognized, however, that such new initiatives should be accommodated within the existing individual infrastructure of the country. It is important to explore ways and means through which continued evolution of individual countries' basic space science activities and international cooperation could be maintained and stimulated.

4. Electronic communication network

19. The participants recognized that the rapid pace of change in basic space science and technology makes the free and efficient flow of ideas and concepts a prime need for participation in basic space science, and therefore urged Member States to plan and implement local electronic communication at or above the level of E-mail networks. Once implemented, or even before the existence of a local (national) network, an internet/μnet/bitnet connection should be established at a suitable location.

20. The United Nations should request Member States to identify support needs without which the above-mentioned facilities cannot be implemented and should act to identify and possibly supply the limited funding needed to support justified requests for the minimum necessary investment to start the implementation of the fundamental needs associated with this.

5. Use of available scientific databases

21. The participants recognized the importance of access to advanced instrumentation and modern extended data sets for the evolution of basic space science disciplines and urged Member States and their scientists to utilize those facilities that are currently available. Much of this could be accomplished through the utilization of existing available databases (such as exist for IUE and EXOSAT and have now become available from the planetary missions), but additional direct use of these facilities would add critical impetus to the development of institutions currently unfamiliar with these facilities.

22. The United Nations should request the scientific institutes that are operating major basic space science facilities to respond to and support requests from developing countries for access to advanced instrumentation and to overcome, in all ways within their capabilities, the perceived problems of gaining access to their facilities.

23. The distribution and acquisition of software, especially in relation to the techniques related to data acquisition, data reduction, image processing and physical modelling, which has already been developed, can save considerable investment.

C. Availability and establishment of scientific facilities

1. Utilization of infrastructural facilities

24. In order to stimulate the utilization of the existing major facilities in basic space science by scientists from developing countries and to enhance their awareness, the United Nations should:

(a) Encourage countries possessing better facilities to open them to developing countries;

(b) Provide short-term fellowships and travel grants for such purposes;

(c) Stimulate the strengthening of the established facilities with specific expertise in the developing countries, so as to promote the existence of regional centres of expertise. These can act as catalysts and training centres for the development of global as well as regional research in basic space science. These centres should strive to stimulate the information flow in their region (e.g., information on institutes and active scientists, funding sources, etc.). Coordination of a regional fund for student exchange in a well-organized programme would be an important contribution.

2. Utilization of ground-based facilities available in developing countries

25. Considering that: (a) the climatological and geographical situation of the Latin American countries presents unique opportunities for observations in basic space science, of which only a few are currently being realized, with very limited access possibilities for the developing countries of the region; (b) there are countries where there is a great demand for observing facilities; and (c) there is technology available in some developing countries to build the instruments and detectors for use at recognized sites, the United Nations should encourage Member States:

(a) To share the existing telescope access with the scientists from the region;

(b) To develop such locations and stimulate the construction of advanced instrumentation, utilizing the techniques identified for basic space sciences;

(c) To improve the rocket and balloon scientific launch facilities in Latin America and to generate support for a strong regional programme in high-energy astrophysics and *in-situ* ionospheric studies;

(d) To develop methods which will assure efficient use of these facilities and encourage the major space agencies to support developing countries' initiatives in the field.

26. In order to help in the development of space science and technology in Latin America, the United Nations should support:

(a) The participation of Latin American technology in the space science projects of the major space agencies;

(b) Hardware development in Latin American countries for these projects.

D. International cooperation in basic space science

1. International cooperation and internationally coordinated basic space science programmes/projects

27. The United Nations should publish a regional directory of basic space scientists and institutions in Latin America. Information on possible sources of funding for training and research support for the different countries will be collected and included in the directory.

28. The United Nations, recognizing that the benefits of the pursuit of basic space science investigations constitute a prime mover of collaboration between Member States, should therefore support and recommend:

(a) Further expansion and continuation of studies of Equatorial Electrojet (EEJ) and the South Atlantic Geomagnetic Anomaly in the context of regional/international collaboration involving:

(i) The reactivation of selected geomagnetic and ionospheric observatories, as well as enhanced support of the networks of such observatories;

(ii) Encouragement of active scientists to participate in and organize international meetings;

(iii) The creation of national committees for the Committee on Space Research (COSPAR) for those Member States not already belonging to that organization, which is a major venue for the coordination of studies in the field;

(b) Development and construction of optical telescopes and radio telescopes with observatory facilities by the Latin American countries for use by the basic space scientists from the region;

(c) Augmentation of the global coverage of INTERMAGNET by supporting the establishment of three observatories in Sri Lanka, eight in Africa and eight in Latin America and the Caribbean;

(d) The establishment of a regional information centre specifically oriented towards astrophysics and atmospheric and geoplanetary sciences for the purpose of:

(i) Disseminating all relevant data obtained under basic space science activities such as remote sensing, atmospheric probing, astrophysics and geophysics to provide vital regional information of fundamental importance for addressing problems related to disaster avoidance and warning;

(ii) Developing a new understanding of the globally important equatorial zone, and therefore developing a plan (in the developing countries) leading to improved resource management and an improvement in living conditions;

(e) Strengthening and reorienting current research activities in the fields of solar-terrestrial, atmospheric and climatic studies, combined with space remote-sensing observations and comparative planetary sciences with participation in the internationally coordinated Global Change and associated programmes such as START, including:

(i) Satellite observations to assess pollutant-rich areas;

(ii) Ground and air truth measurements of solar radiation related to a variety of minor constituents;

(iii) Physical understanding and mathematical modelling of the interlinked processes of global change;

(f) Strengthening current research activities in the fields of astronomy and astrophysics, including:

(i) Experimental, observational and theoretical astrophysics;

(ii) Participation of Latin American astrophysicists in world-wide IAU-supported programmes;

(iii) Systematic galactic and extragalactic observations from equatorial latitudes and the southern hemisphere over the entire electromagnetic spectrum.

29. The participants recognized the difficulties existing in smaller developing countries relating to maintaining and participating in the technological and social developments following naturally from a viable programme in basic space science. They also recognized the problems associated with the relative isolation in which scientists pursue their efforts in these cases. The United Nations should therefore support:

(a) Organization of regional connectivity through data networks;

(b) Stimulation of institutional relations between those regional centres of expertise and local institutes to allow the build-up of a national capability to participate in the rapid scientific, technical and associated cultural development in the world;

(c) Training and further development of human resources, to stimulate and enhance the participation in a balanced development, even for smaller countries;

(d) Active stimulation of students in basic space science through participation in exchange programmes on a regional basis, as well as the exchange of prominent teachers and high-level technicians on a regional basis;

(e) Efforts to create awareness of the importance of basic space science in both decision-makers and the general public.

30. The participants deplored the indiscriminate destruction of carefully built-up infrastructure for basic space science through unstable social conditions. Such destruction was deemed to be considerably more destructive than just the material damage suffered, since important opportunities for rapid progress were lost. The significance of basic space science as a driving force in social renewal was recognized. Basic space science should be carried out with stronger conviction by scientists, and should be associated with more extensive general dissemination programmes.

2. Meetings and symposia on basic space science

31. Considering the growing interest and contribution made by several developing countries in basic space science and the need for further encouraging such activities, the United Nations should organize and support international meetings for in-depth discussions on specific topics of basic space science.

3. Continuation of the workshop on basic space science

32. In order to assure a continued and coordinated evolution of the important issues raised in the present and the previous workshop, it was proposed to hold future basic space science workshops annually, although in the long run they should be held no more than biannually.

33. The United Nations should inquire into the possibilities for hosting the next basic space science workshop in 1993.

4. Space education

34. Considering that basic space science is not taught at superior levels in many developing countries, the United Nations should act to encourage and support:

(a) Introduction of the teaching of basic space science, including experimental techniques, as a part of the curriculum for primary and secondary level education as well as undergraduate and graduate education;

(b) Formation of research facilities at universities so that motivated students may be encouraged to pursue basic space science research;

(c) Organization of summer schools and other similar orientation programmes to train existing faculty in the physical sciences necessary to teach basic space science;

(d) Exchange of teachers, scientists and students to make use of the facilities in Member States and the services of organizations such as IAU and COSPAR;

(e) Organization of seminars, workshops and topical conferences within the developing countries for the benefit of teachers, scientists, students and the general public;

(f) Introduction of popular programmes to encourage and support awareness of basic space science, and the coordination of such activities between Member States;

(g) Establishment of programmes ensuring the availability of basic textbooks and more popular information media at the professional and general public levels;

(h) Distribution and acquisition of educational software for basic space science;

(i) Generation of national career opportunities for professionals trained under the above-mentioned programmes, leading to increased competitiveness of developing countries in the peaceful study and utilization of resources associated with basic space science.

5. International core group

35. In order to pursue and follow up the recommendations made during the Workshop, it has been decided to constitute a core group, under the auspices of the United Nations (Office for Outer Space Affairs), of international scientists consisting of the following members at the functional and advisory levels:

Functional members: Selection of a group of 11 members from the five economic regions and the United Nations

Advisory members: COSPAR, ESA, IAU, ICTP, National Space Development Agency (NASDA) of Japan, National Aeronautics and Space Administration (NASA) of the United States of America.

The creation of the international core group is considered critical to maintaining the impetus generated by the first two workshops on basic space science for the benefit of the developing countries, and will assure the continuity of this important activity in the future.

Annex I

SUMMARY OF PRESENTATIONS

A. Origin of the solar system

1. Star formation. The process of star formation is a very complex and challenging one, among other things because one cannot observe it directly; it occurs deep inside dense cool and opaque nebulae, as if nature were so shy to hide it from the observer's view. To understand how stars are formed one has to rely on what can be observed long after they have emerged from their cocoons; unfortunately sometimes, the clues have been contradictory and misleading. The main observational clues starting from those more removed from the period of star formation and giving to the more intimate views as revealed by infrared and radio observations have been described and discussed. The present understanding of star formation to the cosmogony of double star and planetary systems was stressed.

2. Origin of the solar system. (i) Formation of the terrestrial planets and asteroids: Recent work on planet formation in the terrestrial planet region provides support for models in which planetary growth occurs in two fairly distinct stages. 1. A ''low velocity'' stage in which (at 1 Astronomical Unit [AU]) runaway Moon to Mercury-mass objects grow from 10 km diameter planetesimals on a $\approx 10^5$ year timescale. This timescale lengthens with increasing distance from the Sun, but within a few million years, it is expected that 100-200 such ''embryos'' will form in nearly circular, coplanar orbits in the terrestrial planet region and in the asteroid belt. 2. A ''high velocity'' stage in which these embryos perturb one another into crossing orbits and to velocities ranging from a few km/sec to - 30 km/sec. During this stage, collision and merger of embryos form the terrestrial planets on a $\approx 10^8$ year timescale. Assuming that growth of Jupiter occurs too late ($\geq$1 million years) to prevent the formation of runaway embryos in the asteroid belt, removal of excess mass from the asteroid belt primarily will take place via perturbation of embryos into Jupiter commensurability resonances, followed by ejection from the solar system. If somehow Jupiter was able to restrict the growth of bodies in the asteroid belt to objects the size of the present asteroids, then the clearing of the asteroid belt will probably depend on collisional fragmentation and removal by Poynting-Robertson drag. It may prove possible to distinguish between these alternatives by quantitative inferences based on asteroidal and meteoritic observations.

3. Origin of the solar system. (ii) Formation of the giant planets: Formation of the gas giants, Jupiter and Saturn, differs considerably from that of the terrestrial planets. To form these planets it is probably necessary that: Very massive (10-15 Earth masses) planetary embryos formed by runaway accumulation in $\approx$ 5x

10^6 years. Initiation of a "gas accretion" instability whereby gas (primarily hydrogen and helium) was gravitationally captured by the embryos to form 300 and 100 Earth mass planets. Both of these stages must occur rapidly, before loss of gas from the Solar Nebula in $\approx 10^7$ years. Quantitative calculations show that these events are possible given appropriate distribution of solid material and timing of gas removal. On the other hand, variations in these parameters might cause the formation of planets like Jupiter and Saturn to be fairly rare in other planetary systems. Nevertheless, it may not be surprising that these planets are observed in the solar system. Gas giants provide a gravitational barrier that shield the terrestrial planets from bombardment by comet-like bodies of the primordial outer solar system. Such shielding may be necessary to prevent impact frustration of the evolution of the more complex biological organisms. Little quantitative study has been given to the formation of Uranus and Neptune. Perhaps the most satisfactory models involve the formation of ≈15 Earth mass embryos on a 10^7 - 10^8 year timescale, followed by capture of a relatively small quantity of residual gas from the solar nebula. It is likely that perturbations by the prior-formed giant planets Jupiter and Saturn would preclude bodies of this kind within ≈20 AU and paucity of solid material prevented planet formation at much greater distances.

B. Terrestrial interactions

4. Magnetospheric plasma interactions. The Earth's magnetosphere (including the ionosphere) is the nearest cosmical plasma system and the only one accessible to mankind for extensive empirical study by *in situ* measurements. As almost all matter in the Universe is in the plasma state, the magnetosphere provides an invaluable sample of cosmical plasma from which one can learn to better understand the behaviour of matter in this state, which is so much more complex than that of non-ionized matter. It is therefore fortunate that the magnetosphere contains a wide range of different plasma populations, which vary in density over more than six powers of ten and even more in equivalent temperature. Still more important is the fact that the dual interaction with the solar wind above and the atmosphere below make the magnetosphere the site of a large number of plasma phenomena that are of fundamental interest in plasma physics as well as in astrophysics and cosmology. The interaction of the rapidly streaming solar wind plasma with the magnetosphere feeds energy and momentum, as well as matter, into the magnetosphere. Injection from the solar wind is a source of plasma populations in the outer magnetosphere, although much less dominating than previously thought. One now knows that the Earth's own atmosphere is the ultimate source of much of the plasma in large regions of the magnetosphere. The input of energy and momentum drives large scale convection of magnetospheric plasma and establishes a magnetospheric field and large scale electric current systems that carry millions of ampere between the ionosphere and outer space. These electric fields and currents play

a crucial role in generating one of the most spectacular among natural phenomena, the aurora, as well as magnetic storms that can disturb man-made systems on ground and in orbit. The remarkable capability of accelerating charged particles, which is so typical of cosmical plasmas, is well represented in the magnetosphere, where mechanisms of such acceleration can be studied in detail. In situ measurements in the magnetosphere have revealed an unexpected tendency of cosmical plasmas to form cellular structure, and show that the magnetospheric plasma sustains previously unexpected, and still not fully explained, chemical separation mechanisms, which are likely to operate in other cosmical plasmas as well.

5. Asteroids and comets. These small rocky, metallic, and icy bodies are the remnants of the population of planetesimals from which one believes the planets formed. Spacecraft studies of these small bodies have been initiated in just the past few years, with several investigations of comet Halley and the Galileo spacecraft's recent encounter with the asteroid Gaspra.

6. Meteorites. Every year, more than 100 tons of meteoritic material impacts the Earth. Almost all of these objects are fragments produced by collisions between asteroids. They represent an intermediate-mass portion of a spectrum of asteroidal debris that ranges from 1 to 10 km diameter near-Earth asteroids down to micro-size asteroidal zodiacal dust. Detailed study of these meteorites in the laboratory shows that the asteroids from which they are derived are very primitive bodies. Radiometric dating shows that the crystallization or metamorphism of these rocks occurred 4.45 to 4.55 billion years ago, for the most part before the formation of the Earth. As a consequence, they bear an exquisitely detailed record of events and processes in the early solar system, in the solar nebula, and even contain relics of pre-solar interstellar events. Full use of this remarkable record requires placing the meteorites studied in the laboratory into their planetological context identifying the asteroids from which they are derived, understanding the mechanisms by which the asteroidal fragments are delivered to Earth, and incorporating the formation of the asteroids into a general theory of the formation of planetary systems. Major progress has been achieved on all these problems, but there remain serious unresolved questions. Perhaps the most important of these is the reason why spectrophotometric observations of asteroids seem to imply the near-absence of asteroids with the composition of the most abundant type of meteorite - the "ordinary chondrites".

7. Catastrophic impacts on Earth. The Earth and Moon reside in a swarm of asteroids and comets, which collide and explode from time to time, as revealed by the cratered surface of the Moon. While Earth's atmosphere filters out the smallest impactors, and geological forces have destroyed evidence for many earlier impact craters, the fragile ecosphere of the planet Earth can be dramatically altered by these catastrophic events. A 15 km sized

object apparently impacted near the Yucatan peninsula of Mexico 65 million years ago, and was responsible for mass extinctions of many species of life. Evolution of mammals developed rapidly thereafter, culminating in modern civilization. But the odds are about 1 in 10,000 that modern civilization will be destroyed during the next century by a future impact, unless one takes steps to discover the threatening objects and avert any impending calamity.

8. Volcanoes on the Earth and planets. Comparative volcanology between the Earth and the planets has been addressed as an introduction to the field trip to Poas volcanoes. It has been stressed how studies of terrestrial volcanic fields can be used to interpret features on other planets and discussed various models developed from terrestrial studies which have been applied to interpret the formation of lava flows and other extraterrestrial volcanic features.

C. The terrestrial planets

9. Surface processes - Volcanism and tectonism. The major processes shaping the surfaces of the terrestrial planets are volcanism, tectonism, impact cratering, and erosion. It was discusses how volcanism and tectonism have produced a wide variety of landforms on Mercury, Venus, the Earth's Moon, Mars, and on outer solar system satellites. The influence of planetary parameters on how these processes operate was also addressed and comparisons with the Earth had been made.

10. Surface processes on planets and satellites. With the "flyby" of the Neptune system in the late 1980s by the Voyager spacecraft, all of the planets and major satellites in the solar system have been explored by robotic spacecraft. Geological analyses of the data returned over the past quarter century of solar system exploration has shown that solid surface planets and satellites are modified by a wide variety of processes. The processes can be categorized as (i) endogenic processes originating primarily as a result of heat in the interior of the object under consideration; these processes include volcanism and tectonism, and (ii) exogenic processes originating from exterior sources to the object under consideration; these include impact cratering and surface modifications by wind, water, gravity, etc. In this presentation, consideration had been given to exogenic processes. Evidence for impact cratering is seen for all of the objects in the solar system except the Galilean satellite of Jupiter, Io, which appears to be undergoing very active volcanism, which has obliterated all traces of impact scars. Those planets having dynamic atmospheres experience aeolian, or wind, processes and include Mars, Earth, Venus, Triton (satellite of Neptune), and possibly the Saturnian satellite, Titan. To varying degrees, exogenic processes have modified the surfaces of all planets and satellites.

11. The planet Mercury. Mercury is an extreme planet, a small, metal-rich world bathed in the glare of the Sun. Yet Mercury is a world of surprises, such as the recent discovery of what may be ice caps near its poles.

12. Venus - Exploration via spacecraft. More than two dozen missions have been flown by the United States of America and the former Soviet Union in the exploration of Venus. Spacecraft include landers that have survived on the surface, various "flybys", and orbiting spacecraft that have returned global data for Venus. Data from these missions, combined with various Earth-based observations, have revealed a great deal of information on the nature of the Venusian atmosphere and surface. Because of its similarity in size and mass to the Earth, it is often called the Earth's "sister" planet. Prior to the successful operation of the Magellan spacecraft, there was a great deal of speculation about the potential for Earth-like processes, including plate tectonics and volcanism. Although the geological diversity of Venus was hinted at through the Venera 25/16 radar data, the Magellan mission has provided the first comprehensive view of the complete geological history of Venus. Although volcanic and tectonic processes dominate, exogenic processes, including modification by the wind, are also in evidence. Analysis of the Magellan data is continuing through systematic geologic mapping, topical studies and analysis of geophysical data.

13. Mars - The red planet. After Earth's satellite, the Moon, the planet Mars is probably the best understood of the terrestrial planets in the geological context. Numerous spacecraft have been sent to Mars, including ''flybys'', orbiters, and landers. The first comprehensive view of Mars was gained by the Mariner 9 mission, which began operation in 1971. This successful mission was followed by the landing of the two Viking spacecraft and operation of two orbiters in the mid 1970s. From these missions, the geological history of Mars has been derived. Clear evidence exists for drastically different climates in the past, including times when surface water existed to carve enormous river channels, now left dry. Huge volcanoes dominate the landscape in some areas, while still other regions have been modified extensively by crustal disruption or tectonic processes. Renewed interest in Mars has been prompted by the launch of the Mars observer spacecraft, anticipated in late September 1992. This mission carries an array of instruments to provide global maps of the composition and mineralogy of the surface, insight into the nature of the atmosphere, and topographic data, as high resolution images of the surface. This mission is anticipated to be followed by the Russian Mars 94/96 missions, the Mars Environmental Survey Mission of the United States of America (later this decade), potential European missions involving emplacement of network science instruments, such as seismometers, and the possible launch of a Japanese spacecraft. These approved and anticipated missions demonstrate the high interest by the international community in the exploration of Mars.

14. Mars Observer - A geological and climatological mission. The Mars Observer (MO) spacecraft began its journey to Mars in September 1992 and is scheduled to arrive at Mars in August 1993. The Mars Observer carries a scientific payload of seven instruments that will observe the red planet for one Martian year (687 Earth days) from a 375 km altitude circular polar orbit. The mission will gather information about the Martian atmosphere, surface composition, and help settle the debate over the existence of a magnetic field. The Mars Observer will also participate in the relay of data from a Russian mission to Mars in 1994-95.

15. The special case of Io. Jupiter's satellite Io is of great interest to the topic of planetary volcanology as it is the only extra-terrestrial body known to have large-scale active volcanism. Io's activity, which is thought to be driven by tidal heating, was first detected by the Voyager spacecraft in 1979. The two Voyager encounters provided a wealth of information on Io's volcanic behaviour, however, many questions remain open. Current research work focuses on the current debate about Io's surface composition, reviewing what is known so far from the Voyager data, and discussing the expected results from the Galileo mission, respectively.

D. The Sun

16. Internal structure of the Sun. The Sun as a main-sequence star continuing to be the probe for new ideas in stellar astronomy and physics. The classical solar neutrino problem has been established by the chlorine solar neutrino experiment (USA) over the past 20 years. Additionally, the anti-correlation between the abundance of sunspots and the argon-37 production rate in the chlorine experiment remains to be explained in terms of new neutrino properties or new solar physics. The Kamiokande II experiment (Japan) confirmed the deficit of high energy solar neutrinos as revealed by the chlorine experiment. Most recently, the GALLEX 1 experiment (international collaboration) measured the low-energy solar neutrino flux which seems to be not varying over time and not correlated with solar activity. Based on the conjectured simple internal structure of the Sun, governed by a hydrostatic component and a luminosity-opacity component, much insight has been gained from simple polytropic models such as Eddington's model. Models of the Sun can be constructed for which a non-linear analytic density distribution in terms of a two-parameter family is assumed, for which the system of differential equations for the internal structure of the Sun can be integrated analytically. Hydrostatic equilibrium and energy conservation determine the conditions in the gravitationally stabilized solar fusion reactor. Explicit analytic results obtained for the pressure and temperature distribution in the central region of the Sun can be compared with numerical results emanating from what has come to be known as the Standard Solar Model (SSM).

17. The gallium experiment - Status and first results of GALLEX. The GALLEX experiment for the detection of solar neutrinos by means of a radiochemical gallium detector is operated by groups from Italy, France, Germany, Israel and the United States of America in the Gran Sasso underground laboratory (LNGS) near L'Aquila (Italy). It consists of (i) the target tank containing 101 t of a highly concentrated $GaCl_3$ solution, (ii) a sparking system for desorption of $GeCl_4$, (iii) the absorption system for concentration of $GeCl_4$, (iv) the laboratory scale apparatus for conversion of $GeCl_4$ to GeH_4, (iv) the counter filling station, and (vi) the counters. Possible side reactions by cosmic muons, fast neutrons and α-emitters interfering with the neutrino measurement have been discussed, as well as the purification of the target solution from long-lived, cosmogenic ^{68}Ge. First preliminary results after one year of solar neutrino measurement were presented; they constitute the first measurement of the solar proton-proton neutrinos and amount to 83 SNU (Solar Neutrino Units) ± 19(stat.) ± 8(syst.) (1σ). The measurements including the calibration with a ^{51}Cr-source are continuing.

18. Applications and computational considerations of special functions to solar thermonuclear reaction rate integrals. The first application of Gamow's theory of potential barrier penetration to other than his study of alpha radioactivity was to the thermonuclear source of stellar energy. Atkinson and Houtermans were the first to propose that nuclear reactions may take place in the central region of stars where the motion of nuclei can be assumed to be in thermal equilibrium. The thermonuclear reaction rate between two types of nuclei can be written as $r_{12}=(1-1/2\ \delta_{12})n_1n_2\langle\sigma v\rangle_{12}$, where n_1 and n_2 are the number densities of nuclei of type 1 and type 2, and where $\langle\sigma v\rangle_{12}$ is the reaction probability which is related to the product of the reaction cross section and the flux of particles, averaged over the Maxwell-Boltzmann velocity distribution. As theoretical knowledge and experimental verification of nuclear cross sections increased it was possible to refine the analytic representations for the reaction probability $\langle\sigma v\rangle_{12}$ as derived over the years by Gamow (1949), Bahcall (1966), and Critchfield (1972). These formulae are approximations chosen to be applicable under certain well defined physical conditions. The first approach to derive close-formed representations of the reaction probability was made by Mathai and others. They have shown that, in principle, the reaction probability contains the astrophysical cross-section factor S(E) and its derivatives which has to be determined experimentally, and an integral part of the thermonuclear reaction rate independent from experimental results which can be treated by closed-form representation techniques in terms of generalized hypergeometric functions. Under the Maxwell-Boltzmann approach, the study of nuclear reactions in astrophysical plasmas under various cases (such as resonant, non-resonant, modified non-resonant, non-resonant under electron screening, and so on) leads to a class of complicated reaction rate integrals. It has been shown that this

general class of integrals can be identified with an integral involving the product of two H-functions. This latter integral has been evaluated and computational considerations were provided, including the relative merits of Mathematica and C-compilers for making these computations.

19. Solar neutrinos in relation to solar activity. A serious discrepancy exists between the theoretical value of the solar neutrinos flux calculated from current standard solar models and that obtained from the production of ^{37}Ar atoms at the Homestake station over a period of almost a quarter of a century. Many solar phenomena exhibit variation in the rhythm of the solar cycle. Relation between solar neutrino and solar activity has been investigated by many researchers who have reported contradictory results of correlation, anti-correlation and no correlation. It can be shown that a statistically significant correlation between solar neutrinos and charged particles from the Sun received on Earth exist.

20. Changes in solar irradiance and atmospheric turbidity in Costa Rica during the total solar eclipse of 11 July 1991. Solar global radiation was measured in several places in Costa Rica during the total solar eclipse that occurred on July 11, 1991. In two of these places, Puntarenas and Santa Cruz, measurements in the ultraviolet range (295 - 385 nm) were also taken. In Santa Cruz, a normal incidence pirheliometer with Schott filters OG530 and RG630 was used to measure direct solar radiation in its whole range and in the 530 - 2800 nm and 630 - 2800 nm wavebands, respectively. Global radiation, and consequently direct, diffuse and irradiance in any of the wavebands considered, decreased gradually as the Sun was being eclipsed, and reached zero during the totality, then increased to their normal values. Data registered in Santa Cruz were used to determine Angstroem's atmospheric turbidity parameters α and β. Computations show that between 13:00 and 14:30 local time α decreased and β increased significantly. The values of α and β indicate that on this particular day atmospheric turbidity was high and large particles were more abundant than small ones. The size of hygroscopic particles increased during the eclipse when temperature decreased and relative humidity increased in a relatively short time.

21. Variation of the geomagnetic field in Costa Rica during the total solar eclipse of 11 July 1991. Observations of the geomagnetic field were carried out in three places of Costa Rica, which were located in the path of totality. The observations show that close to totality, it was a significant change in the total intensity, F. Its normal decrease in the afternoon hours was interrupted during a period of about 45 minutes, in which F changed very little. This was due mainly to the small variation in the horizontal intensity, H, during such a period. The deviation of F with respect to normal lasted about 100 minutes; its maximum deviation was about 10 nT and occurred 38 minutes after totality.

The declination, D, also had a small change (an amplitude of about 2.3 minutes) during all the duration of the eclipse. The vertical intensity, Z, and the inclination, I, did not show significant changes.

E. The outer planets

22. Jupiter. This is the largest planet in the solar system, with at least 16 satellites - one bigger than Mercury, one about the same size, and one with active volcanoes - a huge magnetosphere and a system of rings. Jupiter has too little mass to become a star, but still releases more heat from its interior than it receives from the Sun. The changing, colourful cloud patterns one sees in its hydrogen-helium atmosphere provide evidence for chemical reactions among the atmospheric constituents. Heavy elements are slightly enriched in Jupiter's atmosphere, compared to their abundances in the Sun.

23. Saturn. Famous for its rings since Huygens identified them in the 17th century, Saturn is perhaps the most familiar planet. The Voyager missions found much intricate structure in the rings and examined some of the 18 satellites, including mysterious Iapetus, with one hemisphere nearly 10 times darker than the other and Enceladus, closely associated with the E-ring. The internal source of energy on Saturn appears to be the condensation of helium in the planet's deep interior, resulting in a helium deficiency in the atmosphere. Heavy elements in Saturn's atmosphere appear to be enriched compared with the values on Jupiter, but this general trend has exceptions not yet understood. Both Jupiter and Saturn appear to have retained the primordial deuterium to hydrogen ratio that existed in solar nebula gas.

24. Uranus. This planet is different from all the other giants. Lying nearly on its side as it orbits the Sun, it has no detectable internal energy source. 15 satellites circle Uranus in its equatorial plane, where one also finds a system of narrow rings close to the planet. The atmosphere shows a large enrichment of methane and deuterium, compared with Jupiter and Saturn. Unlike these other giants, the visible atmosphere of Uranus is remarkably free of clouds. The planet's magnetic field is oriented at a surprisingly high angle to its axis.

25. Neptune. Like Uranus, Neptune represents a giant planet with a higher density than that of Jupiter and Saturn, again showing a large enrichment of methane and deuterium in its atmosphere. Neptune has 8 known satellites, and a strange ring system that includes discrete arc-like structures in one of the rings. The planet's magnetic field exhibits a similar eccentric orientation to that of Uranus. Unlike its sister planet, however, Neptune does have an internal source of energy. Perhaps as a consequence of the resulting greater vertical convection, the stratosphere of Neptune contains HCN and CO.

26. Pluto, Triton, and Titan. These three objects are grouped together because they are all icy bodies with nitrogen-dominated atmospheres. Although Pluto is usually classified as a planet, (after all, it orbits the Sun and has a satellite!) it is actually smaller than either Triton or Titan. The atmospheres of these bodies have some useful things to tell researchers about chemical evolution at low temperature that may be relevant to the delivery of volatiles to the early Earth. These objects may also be representative of the ''planetesimals'' that secreted to form the cores of the giant planets. Titan is a main focus of the Cassini-Huygens mission, currently under development as a joint ESA-NASA project.

27. Modelling the Jovian planets by a simple analytical algorithm. It can be shown that the structures of the Jovian atmospheres and cores can be modeled by a simple analytical algorithm, which does not require the use of a computer. The method known as the MDV (Motz-Doorish Variable) method was first reported in the Irish Astronomical Journal (1989). It is a method to solve the Stellar Interior Equations (SIE) which dictate the structure of a star and/or the Jovian planets. The results have been compared mainly, to the work of Stevenson (1982) and found to be very agreeable. Tabulated results of both the atmospheres and cores of Jupiter, Saturn, Uranus and Neptune have been provided. This method has also been applied to the protoplanetary stage.

28. Bodies of ice. Measurement of the low density, and the direct observation of surface ices for some planets, have encouraged the creation of planetary models having large mantles of ice surrounding a small rocky core. These models and possible effects on remote sensing of the surfaces of these icy bodies have been reviewed.

29. Surfaces of ice. Ices have been observed on most planetary bodies from Earth outward. The history of remote sensing of ices, techniques used to determine the existence and extent of ices on planetary surfaces, and the current understanding of the distribution, composition, and stability of ices within the solar system were discussed.

F. Life: A planetary phenomenon

30. Comets, interstellar dust and the origin of life. Over the past decade it has become clear that cometary dust as well as interstellar grains are predominantly comprised of complex organic material including aromatic and aliphatic structures. It is also generally conceded that the early Earth conditions were unfavourable for the production in situ of pre-biotic material. A connection between interstellar organics, comets and the origin of life, which was suggested as early as 1975 by Hoyle and Wickramasinghe, now appears to be inevitable. The question that remains to be resolved is whether extraterrestrial pre-biotic

material arrived to be assembled into living systems, or is it likely that preformed self-replicable living structures arrived from outside?

31. Why visit Titan and Europa? The special attraction of Titan for studies of the origin of life stems from the fact that this large satellite of Saturn has a reducing atmosphere in which chemical evolution is taking place today. Simple compounds such as methane and nitrogen are being broken apart by electron bombardment and solar ultraviolet light and the fragments of these molecules are forming more complex substances. One can see the first steps in this process in the small molecules discovered by Voyager 1: C_2N_2, C_3H_8, etc. One knows larger molecules are being formed because they make up the aerosol that fills the atmosphere. One wants to know what these compounds are and what pathways were taken to produce them. Europa interests us because it may have a layer of liquid water immediately below its icy crust. If so, it is important to know whether or not any chemical evolution is occurring in this environment.

32. Synthesis of organic compounds - A simulated Titanian atmosphere: An educational model. An inexpensive and practical model for teaching about biochemistry and the origins of life was described. In the 1950's Stanley Miller performed an experiment in which gases assumed to compose the primary Earth atmosphere were placed in a glass vessel. They were then energized with "artificial lightning". The results were many organic compounds, which thus proved the processes of chemical evolution. The same type of experiment can be performed on a simulated Titanian atmosphere which if/when successful can show that organic chemistry is possible on Titan. The apparatus is inexpensive as are the chromatography techniques, which makes this type of research very valuable to students in developing countries.

33. Life on Mars. Although the Viking results may indicate that Mars has no life today, the possibility exists that Mars may hold the best record of the events that led to the origin of life. There is direct geomorphological evidence that in the past Mars had large amounts of liquid water on its surface. From a biological perspective the existence of liquid water, by itself, motivates the question of the origin of life on Mars. From studies of the Earth's earliest biosphere one knows that by 3.5 Gyr. ago, life had originated on Earth and reached a fair degree of biological sophistication. If Mars did maintain a clement environment for longer than it took for life to originate on Earth, then the question of the origin of life on Mars follows naturally. Studies in the Antarctic and the Siberian permafrost provide lessons in how life on Mars may have persisted.

34. The origin of life in the solar system. Currently one lacks a fundamental theory for life and with only one example to study extrapolation is best based on ecosystems found on Earth. Field

studies of life on Earth - particularly in extreme environments - indicate that liquid water is the quintessential requirement for life. Thus, the presence of liquid water provides the most useful environmental criteria for searching for life on other planets. In the present solar system, liquid water, and hence life, is definitely found only on Earth. There is convincing evidence that liquid water existed on Mars early in its history. Europa and comets are speculative candidates for liquid water habitats. Mars, 3.5 Gyr ago, is the most promising site for life in our solar system other than the Earth.

35. Detectability of extraterrestrial civilizations activities. The possibilities to establish contact or detecting technological extraterrestrial activities according to the laws of nature as they are known has been reviewed. The efficiency among the boson astronomy (photons and gravitons), with particle astronomy (neutrinos, cosmic rays and macroscopic particles or objects) as well as the use of direct techniques (interstellar space probes or spaceships) were compared. Assuming that there is a certain number **N** of civilizations in the galaxy, at mankind's or beyond mankind's level of technical facility, and considering that each civilization is on or near a planet of a main sequence star where the asteroid/comet impact hazards is considered as serious as on Earth, the detectability of some of the "intelligent activities" developed by the extraterrestrial civilizations to warning these dangerous impacts using the present and near future SETI programs have been studied.

G. Cosmic physics

36. Astrometry in the Kerr field. The basis for a non-static relativistic astrometry, i.e. one in which one takes into account the rotation of the Sun has been studied. In order to accomplish such a task, the following procedure had been chosen: For this purpose the Kerr metric (interpreted as the space-time of a rotating body, with parameters M, a and angular momentum J = Ma) represents the field of the Sun (body with slow rotation). Then, expanding it in a power series of a, the resulting space-time (Lense-Thirring-like metric, with $J = J_z = I\Omega$) can be transformed again by means of the harmonic condition of the Schwarzschild metric. Thus, by adding the missing components of J through the definition of the vector potential V and expanding the space-time (quasi-harmonic form) in a power series of the gravitational field U, and by just keeping only the PPN order, allows to assign to each term of these new metric tensor components certain parameters or coefficients in agreement with post-post-Newton (PPN) theory, in order to have a workable metric for this purpose. The light rays path coming from a star and its corresponding gravitational time delay associated with it are calculated using the metric described above. Thus in order to achieve this the light deflection is divided in two parts: One that is parallel to the straight line path (this part is related with the associated gravitational time

delay) and the other perpendicular to the previous direction (it is related to how the light ray is deflected). The subsequent application of perturbation theory allows to find the solution (the post-Newtonian (PN) order was already found by Will) for the light rays path in the solar field, and associated with this result one obtains the gravitational time delay. The notion of the observer's rest frame and the stellar compass was presented. With the aid of the first concept one can determine the angle (independent of the reference frame) between two light rays (null vectors K and K'), one originating in the star, taken as the reference, and a second one from another star taken as the source (both rays projected onto the observer's rest frame). From this result one finds the PN, $P^{3/2}$ N and PPN contributions to the light deflection angle, when one moves the reference stars to the place where the Sun is located. Verification has been provided for the predicted values by Epstein-Shapiro for the light deflection of a ray that grases the solar limb. Furthermore, the tetrads of the Kerr metric in its parametrized PPN form have been chosen and applied to the formula for the angle between two light rays referred above with the purpose of determining the corresponding directional cosines (depending on the reference frame). In other words, the angle that a light ray, originating in a star (projected onto the observer's rest frame), forms in the local reference frame has been calculated. Additionally, one can calculate the PN, $P^{3/2}$ N and PPN contributions to the right ascension and to the declination that represent the position of a fixed star on the celestial sphere. Thus a stellar catalogue can be drafted.

37. A remark on the one-photon-pair annihilation in strong magnetic fields. Specific results on a quantum electrodynamical feature of the one-photon-pair annihilation which completes the calculations already done for this process have been reported. Most of the calculations related to this process have been usually carried out utilizing the wave functions obtained from the Dirac equation in the Landau gauge $\mathbf{A}_a = (0,B\,x,0)$, where B is oriented along the z-axis (Johnson and Lippman, 1949, referred to as JL). The eigenstates of the Dirac Hamiltonian as it was introduced by JL do not consider the coupling to the radiation field and consequently they reflect only for $p_z=0$ the same linear combination of the two degenerate polarization states. Furthermore, in subsequent publications where these eigenstates are employed, they must be considered with caution as far as cases with $p_z\neq 0$ and $N>0$ are concerned. Sokolov and Ternov (1968) have chosen wave functions which are eigenfunctions they called transverse polarization states of an operator which may be interpreted as the component of the magnetic moment of the electron operator along the external magnetic field B. The gauge chosen in order to get such eigenfunctions is $\mathbf{A}_b = (-By/2,\ Bx/2,0)$, where $\mathbf{A}_b = \mathbf{A}_a + \nabla\Lambda$ with $\Lambda = -Bxy/2$). The use of polar coordinates seems for this particular problem of particular interest. Further, there is another set of eigenstates used by Herold (1979) and Herold and collaborators (1983) that denominated the proper polarization states of the

electron which take into account the coupling of the electron to the radiation field by the interaction Hamiltonian, thus removing the degeneracy of the 2 polarization states in excited Landau levels. All this raised the question how the form of the transition rate depends on the choice of the gauge for the external homogeneous constant magnetic field and how the corresponding spinors couple to the external field when they are applied to a radiation process, i.e., one-photon-pair annihilation in external magnetic strong magnetic field. Additionally, Harding (1986) argued that the eigenstates used by Daugherty and Bussard (1980), which are the same as in JL, reproduce the correct results if the transition rate function will be averaged over the electron and positron eigenstates. Finally, the transition rate function for the one-photon-pair annihilation in a strong magnetic field using the Sokolov and Ternov eigenstate $| \pm >$, as far as $p_z = 0$ and $N > 0$ is concerned, was presented. The difference between the expression for the transition rate by using the Sokolov and Ternov eigenstates and the one calculated by Wunner and collaborators (1986), is just the function $I_{s,s'}$ which corresponds to the degeneracy of the orbit centre of the electrons characterized by the quantum numbers s and s'.

38. On the natural linewidth of absorption lines in strong stellar magnetic fields. In recent times the interest to explain the existence of a singularity at lower frequencies ($\omega=0$) in the differential cross section for scattering of photons by electrons, exposed to a homogeneous magnetic field, for the transitions between the Landau levels N and N', has greatly increased. A calculation of the cross section for the absorption of radiation by an electron in a strong stellar magnetic field in the Wigner-Weisskopf approximation, in order to explain this kind of singularities in the Compton cross section, has been given.

H. Cosmic Background Explorer (COBE): Observation and theory

39. Hydrodynamic stability and the formation of structures in the Universe. The role played by the linear and non-linear hydrodynamic stability (instability) in the formation (destruction) of cosmic structure (stars, clouds, stellar clusters, galaxies ...) was outlined. In particular, explicit criteria for supercritical stability, subcritical instability, asymptotic stability, and superexponential instability for thermal structures of interest in astrophysics have been discussed. Applications of the above general criteria to the primordial plasma, burning cores of star, the solar atmosphere and the interstellar medium (atomic and molecular clouds) were emphasized.

40. Evolution of perturbations after decoupling. A program for the reconstruction of density fluctuations and peculiar velocity field maps for different values of z (the redshift), from the time of matter-radiation decoupling up to the present epoch has been reviewed. The recent measurement of the sky map for temperature

fluctuations of the Cosmic Background Radiation (CBR) provides, at least in a statistical sense, "initial conditions" for the origin of structure in the Universe. On the other hand, during the last few years there has been a growing number of data about the distribution and peculiar velocity of matter for $z \leq 5$, which gives much information concerning the non-linear phase of the evolution of large-scale structure. Analytical methods can be employed to simulate this phase. Such equations, and other important relations among relevant variables, have been developed through the use of the BBGKY hierarchy, or integrations of moments of the Vlasov equation. Some of the simplifying assumptions made, such as self-similarity and scale invariance, were not taken up as an integral part of the computational scheme, but instead were left to justify themselves as a possible outcome of the strongly non-linear regime. Moreover, "virialization" of different parts of the matter distribution was expected to come naturally out of the evolution of the system without the need to impose a special form of the solution for the peculiar velocity field. Finally, it was checked whether this approach connects smoothly with the underlying assumption in present calculations of the peculiar velocity field, such as in POTENT, where the velocity field, averaged over some large scale, can be derived from a potential scalar function.

41. Computational aspects of the gravitational instability problem for a multicomponent cosmological medium. To explain the observed large-scale structure of the Universe, the clusters of galaxies and conglomerates of them, the cosmological models require some input that the early Universe contained density fluctuations from which such large-scale structures might grow. Recently, COBE found a temperature variation $\Delta T/T=6 \times 10^{-6}$ in the cosmic microwave background that can be taken as a surrogate for density perturbations from a time well before the separation of radiation from matter. The COBE result seems to be consistent with theories of large-scale structure formation that are dominated by nonbaryonic dark matter. Three main types of particles take part in the formation of structure in the Universe as well as in governing its subsequent development at about 10^4 years after the Big Bang, a time when matter density becomes equal to radiation density and when radiation domination is over: particles of nonbaryonic nature composing dark matter, baryons, and photons. Newtonian theory can be used for the description of the evolution of small perturbations in a multicomponent medium thereby assuming that all velocities are small compared to the speed of light. Closed-form representations of the solutions of the linear perturbation equations have been presented. These representations, which are valid for irregularities on any scale, can be used to analytically interpolate between known approximate solutions which are valid for large-scale (early time) inhomogeneities and for small-scale (late time) inhomogeneities. Methods to derive computable forms of the perturbations are outlined.

42. Mapping the galaxy: The Andes-Berkeley-INPE project. Mapping of the diffuse radio emission of the Milky Way is not only important in its own right but also necessary for the analysis and interpretation of Cosmic Background Radiation data. It was shown that measurements of anisotropy and spectral distortions in the CBR are limited by uncertainties in the knowledge of the galactic component. A program has been implemented for conducting an extended observational campaign to map the total sky brightness at several frequencies from 408 MHz to 1.5 GHz. The requirements and characteristics of the instruments and of the observing sites were presented.

I. Space missions in astronomy

43. The Hubble Space Telescope - Recent results and future plans: A brief history of the Hubble Space Telescope (HST), including the story of the spherical aberration in the primary mirror and the story of how this observatory has nevertheless become a premier research tool has been given. Recent results from HST have been shown, and plans for servicing the observatory at the end of 1993 were outlined.

44. Use of IUE data in advancing the knowledge of interacting binary stars. The use of IUE data in advancing our knowledge of the gaseous structure in interacting binaries was described. The existence of non-thermal sources of energy, their possible location and number, the velocity and temperature profiles of the gaseous structure and the effect of wind collision are some of the results that have come out of the UV study of those objects. The importance of the availability of IUE archive data was stressed.

45. Early results from the ROSAT mission. Since almost two and a half years the satellite observatory ROSAT is exploring the sky in the soft X-ray regime. The first All Sky Survey with an imaging X-ray telescope resulted in the detection of about 60 000 X-ray objects, an order of magnitude higher number than known before ROSAT. This large data base is now being used for detailed studies on individual objects, on selected samples from specific object classes and on general statistical source classification. Research topics range from investigations of stellar populations, of extended structures in the soft X-ray background like supernova remnants, studies of the properties of normal and active galaxies and of the hot gas in clusters of galaxies up to observations of the most distant quasars in the Universe. The All Sky Survey, performed in the early part of the mission, has in the meantime been complemented by appreciably deeper exposures on thousands of individual objects, measuring in detail their spatial, spectral and timing behaviour. Parallel to the X-ray research a high number of correlated studies have been arranged, specifically with the optical and the radio regimes, aiming for an understanding of the multi-wavelength appearance of the different astronomical objects.

46. ROSAT data handling. Data handling for the German X-ray satellite observatory ROSAT is based on the products originating from the initial processing of all data in the 4 ROSAT Scientific Data Centres in Germany (2), the United States of America and the United Kingdom. At these places a homogeneous calibration of all raw data is performed followed by a standard analysis of the source content in the observed sky images. This analysis results in a list of key parameters for all detected sources including the spectral and timing behaviour in case of stronger sources. Through the Standard Analysis the observer therefore obtains very early after the observation an overview on the quality and the outcome of the observation and can use this information as a starting point for a more detailed analysis. For this purpose the Data Centres provide ROSAT observers with interactive image analysis software systems allowing to perform many of the analysis tasks typically applied in this field of astronomy. With begin of November 1992 observational data enter the ROSAT Public Data Archive from where they can be requested by every interested scientist. As soon as a status is reached where most of the calibration and data evaluation problems have been understood also the results of the Standard Analysis processing will be transferred to the ROSAT Result Data Archive.

47. Activities of the Argentine Space Agency - The SAC-B project. A brief outline of the organization of space activities in Argentina since they started in 1960, as well as the present structure (as of 1991) and plans of the Argentine Space Agency was given. The aim and characteristics of the SAC-B scientific (astronomical) satellite project, its present status, and the instrumentation that will go onboard was described.

48. A balloon-borne imaging telescope for high-energy astrophysics. An imaging telescope for observations of Southern Hemisphere celestial sources in the energy band from 50 keV to 5 MeV onboard stratospheric balloons was described. The detector is a 41cm diameter, 5cm thick NaI(Tl) crystal coupled to 19 photomultipliers. The imaging capability is provided by a 19x19 element MURA-based mask mounted in an one-piece mask-antimask configuration. The angular resolution is of the order of 15 arcmin over a field of view of approximately 15 degrees. The platform, capable of pointing and stabilization with an accuracy of 5 arcmin in both azimuth and elevation, was also described.

49. The Cassini-Huygens mission. This mission will consist of a Saturn orbiter with a probe to be sent into the atmosphere of Titan. The Huygens probe is being built by ESA, the orbiter by NASA. Instruments and investigators from both Europe and the United States of America are involved in both components of the mission. Launch is scheduled for 1997, with arrival at Saturn in the year 2004. The orbiter payload consists of instruments for studying the planet, its rings, magnetosphere, and satellites, including a radar for sensing the surface of Titan. The probe will

study the atmosphere and surface of Titan throughout its 2.5 hour descent, and may make additional measurements if it survives its landing.

J. Education for space science

50. Mission to the Universe - Sharing space science through education. In 1992 and 1993, more than 20 astronomical observatories are, or will be, operating in space. This fleet of space observatories represents an extraordinary effort on the part of the human species to map the observable Universe across the spectrum. At the 2nd Pacific International Space Year Conference in Hawaii (Oct. 1991), an international group of astronomers dubbed this effort ''Mission to the Universe''. A brief overview of the ongoing effort was provided and the question of why, in a time of many pressing global problems, the nations of the world should invest resources in a space science effort like Mission to the Universe, was addressed. Six immediate benefits provided by Mission to the Universe were described: (i) New perspectives that help us to understand ourselves; (ii) Inspiration for education; (iii) A model of international cooperation; (iv) Development of technology; (v) Training of scientists and engineers; and (vi) A vision for the future to help humankind see the road ahead, if one solves the problems of the present. How Mission to the Universe might be used to inspire broader education, particularly in science, in developing nations was also addressed.

51. NASA's Initiative to Develop Education through Astronomy (IDEA). The Initiative to Develop Education through Astronomy represents a commitment by the NASA Astrophysics Division to promote excellence in education. IDEA is based on small augmentations of funding and modest additional effort by scientists, and is dedicated to making high-quality, accurate astronomical information available to educators and to the general public. IDEA's objectives include taking advantage of the universal appeal of astronomy to enhance mathematical, technological and scientific literacy, and increasing the representation of science of women and people of all cultures. Preliminary indications show image processing to be an effective and fun way to study the application of science and mathematics to "all world" applications, as represented by digital imagery. The use of image processing is also an innovative method for engaging students in inquiry and discovery learning. NASA has now developed an on-site teacher education programme for schools with the appropriate hardware. NASA has also developed a broad range of curricular materials built around image processing for a variety of science and mathematics content areas.

52. Activity-based astronomy instruction at low cost. The efficacy of activity-based instruction in the sciences has been well established in the literature. Unfortunately, activity-based instruction in astronomy is difficult due to limitation on

equipment and accessibility to a dark, night sky. Several low-cost activities that directly engage students using inexpensive materials and equipment have been described. Some of these materials have been developed at the Harvard-Smithsonian Centre for Astrophysics with assistance from the US National Science Foundation and others have been developed independently by researchers. A proposed Spanish-language version of some of these materials was discussed.

Annex II

PROGRAMME OF THE WORKSHOP

Venue: San José, Costa Rica

DATE/TIME	SUBJECT	SPEAKER
2 NOVEMBER 1992		
8 - 9 a.m.	Registration	
	Inauguration and opening ceremony	
9 - 9.10 a.m.	Welcome address	W. Fernandez
9.10 - 9.30 a.m.	Address by the Representative of the United Nations	N. Jasentuliyana
9.30 - 9.40 a.m.	Address by the Rector of the University of Costa Rica	C. Quesada
9.40 - 9.50 a.m.	Address by the Minister of Science and Technology of Costa Rica	O. Morales
	Chairperson: H.J. Haubold (UN)	
10.15 - 11.00 a.m.	European Space Agency Lecture: Archives and their relation to the development of fundamental scientific ideas	W. Wamsteker (ESA)
	Chairperson: A. Ocampo (USA)	
11 - 11.45 a.m.	The Planetary Society Lecture: Catastrophic impacts on Earth	C.R. Chapman (USA)
	Session: Origin of the solar system	
	Chairperson: C.-G. Faelthammar (Sweden)	
11.45 a.m. - 12.30 p.m.	Star formation	A. Poveda (Mexico)

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12.30 - 1.15 p.m.	Origin of the solar system	G. Wetherill (USA)

Session: Terrestrial interactions

Chairperson: K. Pope (USA)

2.45 - 3.30 p.m.	Magnetospheric plasma interactions	C.-G. Faelthammar (Sweden)
3.30 - 4.15 p.m.	Asteroids and comets	C.R. Chapman (USA)
4.30 - 5.15 p.m.	Meteorites	G. Wetherill (USA)

3 NOVEMBER 1992

Session: Terrestrial interactions (continuation)

Chairperson: L. Gonberoff (Chile)

9.00 - 9.45 a.m.	Magnetospheres and solar interaction I	M. Acuna (USA)
9.45 - 10.30 a.m.	Magnetospheres and solar interaction II	M. Acuna (USA)

Session: The terrestrial planets

Chairperson: G.A. Lemarchand (Argentina)

10.45 - 11.30 a.m.	Surface processes: Volcanism and tectonism	R. Lopes (USA)
11.30 a.m. - 12.15 p.m.	Surface processes on planets and satellites	R. Greeley (USA)
12.15 - 1.00 p.m.	The Moon	A. Ocampo (USA)
2.30 - 3.15 p.m.	The planet Mercury	C.R. Chapman (USA)
3.15 - 4.00 p.m.	Venus: Exploration via spacecraft	R. Greeley (USA)

4.15 - 5.00 p.m.	Mars: The red planet	A. Ocampo R. Greeley (USA)
5.00 - 5.45 p.m.	The special case of Io	R. Lopes (USA)

Special session: International basic space science activities

Chairperson: M. Acuna (USA)

6.00 - 6.45 p.m.	UN activities in basic space science	N. Jasentuliyana (UN)
6.45 - 7.30 p.m.	World Astronomy Days (WAD)	W. Wamsteker (ESA)

4 NOVEMBER 1992

Session: The Sun

Chairperson: M. Acuna (USA)

9 - 9.45 a.m.	Internal structure of the Sun	H.J. Haubold (UN) A.M. Mathai (Canada)
9.45 - 10.30 a.m.	The gallium solar neutrino experiment	R.v. Ammon (Germany)

Session: The Sun (continuation)

Chairperson: H.J. Haubold (UN)

10.45 - 11.30 a.m.	Applications and computational considerations of special functions to solar thermonuclear reaction rate integrals	W.J. Anderson A.M. Mathai (Canada) H.J. Haubold (UN)
11.30 a.m. - 12.15 p.m.	Solar neutrinos in relation to solar activity	D. Basu (West Indies)
12.15 - 1.00 p.m.	Changes in solar irradiance and atmospheric turbidity in Costa Rica during the total solar eclipse of 11 July 1991	W. Fernandez V. Castro J. Wright H. Hidalgo A. Saenz (Costa Rica)

2.30 - 3.15 p.m.	Variation of the geomagnetic field in Costa Rica during the total solar eclipse of 11 July 1991	G. Leandro J. Brenes W. Fernandez (Costa Rica)

Special session: Establishment of astronomical observatories in developing countries

Chairperson: H.J. Haubold (UN)

3.15 - 3.45 p.m.	National astronomical observatory in Peru - A proposal	M. Ishitsuka K. (Peru)
3.45 - 4.15 p.m.	Setting up a national astronomical observatory in Sri Lanka	N.C. Wickramasinghe (UK)
4.15 - 4.45 p.m.	Possibilities for astronomy in Peru	M.L. Aguilar (Peru)

5 NOVEMBER 1992

Session: The outer planets

Chairperson: R. Lopes (USA)

9 - 9.45 a.m.	Jupiter	G. Ballester (ESA)
9.45 - 10.10 a.m.	Saturn	T. Owen (USA)
10.10 - 10.30 a.m.	Uranus	T. Owen (USA)
10.45 - 11.30 a.m.	Neptune	C.R. Chapman (USA)
11.30 a.m. - 12.15 p.m.	Pluto, Triton, and Titan	T. Owen (USA)
12.15 - 1.00 p.m.	Modelling the Jovian planets by a simple analytical algorithm	J.F. Doorisn (USA)
2.30 - 3.15 p.m.	Bodies of ice	W. Smythe (USA)
3.15 - 4.00 p.m.	Surfaces of ice	W. Smythe (USA)
4.15 - 5.00 p.m.	Present understanding of the formation of giant planets	G. Wetherill (USA)

6 NOVEMBER 1992

Session: Life - A planetary phenomenon

Chairperson: Th. N. Gautier (USA)

9 - 9.45 a.m.	Comets, interstellar dust and the origin of life	N.C. Wickramasinghe (UK)
9.45 - 10.30 a.m.	Origin of terrestrial planet atmospheres	T. Owen (USA)
10.45 - 11.30 a.m.	The Earth as a planet	K. Pope (USA)
11.30 - 12.15 p.m.	Why visit Titan and Europa?	T. Owen (USA)
12.15 - 1.00 p.m.	Synthesis of organic compounds - A simulated Titanian atmosphere: An educational model	J.F. Doorish (USA)

Session: Life-A planetary phenomenon (continuation)

Chairperson: M. Schuch (Brazil)

2.30 - 3.15 p.m.	Life on Mars	C. McKay (USA)
3.15 - 4.00 p.m.	The origin of life in the solar system C. McKay	(USA)
4.15 - 5.00 p.m.	Detectability of extraterrestrial civilizations activities	G.A. Lemarchand (Argentina)
5.00 - 5.30 p.m.	Volcanoes on the Earth and planets	R. Lopes (USA)
5.30 - 6.00 p.m.	Introduction to the Poas field trip	E. Malavassi (Costa Rica)

7 NOVEMBER 1992

8 a.m. - 6 p.m. Field trip: Poas volcano

8 NOVEMBER 1992

Transfer to Bogota (Colombia)

PROGRAMME OF THE WORKSHOP

Venue: Bogota, Colombia

DATE/TIME	SUBJECT	SPEAKER
9 NOVEMBER 1992		
8 - 9 a.m.	Registration	
	Inauguration and opening ceremony	
9 - 9.10 a.m.	Welcome address	E. Posada
9.10 - 9.20 a.m.	United Nations address	P. Lala
9.20 - 9.30 a.m.	Address by the Rector of the University of the Andes	A. Infante
9.30 - 9.40 a.m.	Address by the Foreign Minister of Colombia	N.S. de Rubio
	Session: Dark matter and formation of structure in the Universe	
	Chairperson: A. Ocampo (USA)	
10.30 - 11.15 a.m.	International Space Year Lecture: Detection of astrophysical neutrinos	R.v. Ammon (Germany)
11.15 a.m. - noon	Structure and evolution of the Universe as a consequence of elementary particle properties I	J. Kleczek (Czechoslovakia)
noon - 12.45 p.m.	Structure and evolution of the Universe as a consequence of elementary particle properties II	J. Kleczek (Czechoslovakia)
	Session: Cosmic physics	
	Chairperson: H.J. Haubold (UN)	
2.30 - 3.15 p.m.	Astrometry in the Kerr field	J. Paez (Costa Rica) P. Frutos (Germany)

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3.15 - 4.00 p.m.	A remark on the one-photon-pair annihilation in strong magnetic fields	J. Bonatti J. Paez L. Semionova (Costa Rica)
4.15 - 5.00 p.m.	On the natural linewidth of absorption lines in strong stellar magnetic fields	E. Barbosa (Colombia) J. Bonatti (Costa Rica)

10 NOVEMBER 1992

Session: Cosmic Background Explorer (COBE): Observation and theory

Chairperson: J. Sahade (Argentina)

9 - 9.45 a.m.	COBE results and their cosmological implications	S. Torres (Colombia)
9.45 - 10.30 a.m.	Hydrodynamic stability and the formation of structure in the Universe	M.H. Ibanez (Venezuela)
10.45 - 11.30 a.m.	Evolution of perturbations after decoupling	R. Bautista (Colombia)
11.30 a.m. - 12.15 p.m.	Computational aspects of the gravitational instability problem for a multicomponent cosmological medium	A.M. Mathai (Canada) H.J. Haubold (UN)
12.15 - 1.00 p.m.	Mapping the galaxy: The Andes-Berkeley-INPE project	S. Torres (Colombia) G. de Amici G. Smooth (USA) T. Villela (Brazil)

Session: Cosmic Background Explorer (COBE): Observation and theory

Chairperson: M. Fernandez (Costa Rica)

2.30 - 3.15 p.m.	Non-linear thermal instabilities in the interstellar medium	A. Parravano (Venezuela)
3.15 - 4.00 p.m.	A balloon-borne imaging telescope for high-energy astrophysics	T. Villela (Brazil)
4.25 - 7.00 p.m.	Plenary session: Cooperation in basic space science in Latin America and the Caribbean	

Chairperson: W. Wamsteker (ESA)
Rapporteurs: S. Torres (Colombia)
M. Fernandez (Costa Rica)

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11 NOVEMBER 1992

Session: Space missions in astronomy

Chairperson: S. Torres (Colombia)

9 - 9.45 a.m.	The Hubble Space Telescope (HST): Recent results and future plans	J. Bennett (NASA)
9.45 - 10.30 a.m.	International Ultraviolet Explorer (IUE)	W. Wamsteker (ESA)
10.45 - 11.30 a.m.	Use of IUE data in advancing the knowledge of interacting binary stars	J. Sahade (Argentina)
11.30 a.m. - 12.15 p.m.	Early results from the ROSAT mission	H.-U. Zimmermann (Germany)
12.15 - 1.00 p.m.	ROSAT data handling	H.-U. Zimmermann (Germany)

Session: Space missions in astronomy (continuation)

Chairperson: T. Villela (Brazil)

2.30 - 3.15 p.m.	Activities of the Argentine Space Agency: The SAC-B project	J. Sahade (Argentina)
3.15 - 4 p.m.	Gamma ray astrophysics	N. Martinic (Bolivia)
4.15 - 5 p.m.	The problem of stellar membership in open clusters	A. Uribe E. Brieva (Colombia)
5 - 5.45 p.m.	The Radioastronomy Project - The National Agreement: CNPq/National Observatory and Federal University of Santa Maria	N. Schuch (Brazil)

12 NOVEMBER 1992

Session: Education for space science

Chairperson: A.M. Mathai (Canada)

9 - 9.45 a.m.	Mission to the Universe - Sharing space science through education	J. Bennett (NASA)
9.45 - 10.30 a.m.	NASA's Initiative to Develop Education through Astronomy (IDEA)	C. Morrow (NASA)
10.45 - 11.30 a.m.	Activity-based astronomy instruction at low cost	D. Hoff (USA)

11.30 a.m. - 1.00 p.m.	Working Group session
	Chairperson: W. Wamsteker (ESA)
2.30 - 4 p.m.	Working Group session (continued)
4.15 - 6 p.m.	Plenary session: Cooperation in basic space science in Latin America and the Caribbean
	Chairperson: J. Sahade (Argentina)

13 NOVEMBER 1992

9 - 10.30 a.m.	Plenary session: Cooperation in basic space science in Latin America and the Caribbean
	Chairperson: W. Wamsteker (ESA)
	Rapporteurs: H.J. Haubold (UN) S. Torres (Colombia)
10.45 - 11.30 a.m.	Closing session
	1. Report by the Chairperson of the plenary session
	2. Adoption of the report

Annex III

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